

## ***Interactive comment on “Drought in forest understory ecosystems – a novel rainfall reduction experiment” by K. F. Gimbel et al.***

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### General comments

1. Referee: The Results section, in places, fails to present statistical justification for the claims made and I had considerable difficulty in understanding two of the figures (Figures 4 and 6). We are told only that drought conditions had no effect, in this initial period, on growth parameters. I would, nevertheless, have liked to see some of the supporting data - perhaps in an appendix.

Answer: In agreement with referee 1 we have now focused the discussion as well as the conclusion to the ecosystem responses on the short-term avoiding speculation on the system behavior under longer-drought exposure. (see also comments

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2 and 23). Concerning the Figures 4 and 6, please see the answers to comments 13 and 15. Further data on growth parameters is already published in a paper by Baudis et al. 2014 (Baudis, M., Ellerbrock, R. H., Felsmann, K., Gessler, A., Gimbel, K., Kayler, Z., Puhlmann, H., Ulrich, A., Weiler, M., Welk, E. and Bruehlheide, H.: Intraspecific differences in responses to rainshelter-induced drought and competition of *Fagus sylvatica* L. across Germany, *Forest Ecology and Management*, 330, 283–293, doi:10.1016/j.foreco.2014.07.012, 2014). We now inserted a reference to this paper in the text (section 2.4).

2. Referee: The Discussion again makes a number of claims that appear unsupported by the results as presented here. The question of whether the authors expect drought effects to be more pronounced over short or long periods is rather vague here – in contrast with the final sentence in the Conclusion.

Answer: We have now focused the discussion as well as the conclusion to the ecosystem responses on the short-term avoiding speculation on the system behavior under longer-drought exposure.

3. Referee: In my opinion, the detailed aims of this pilot study could be made more explicit at the start (e.g. reduction of rainfall whilst avoiding any associated effects on air temperature or humidity). Those same points could then be summarised in the Conclusion.

Answer: We agree with the referee and integrated the following sentence in the Introduction section and tied the conclusion back to these aims: “The aim of this study was to apply a realistic reduction of precipitation whilst avoiding any associated effects on air temperature or humidity and to observe the initial drought effects on the forest-understory-soil-system.”

### Specific comments

Introduction

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4. Referee: 14321-15 The opening sentence is perhaps too bold – what about soil structure, biota, nutrient availability?

Answer: We agree with the referee and changed the sentence to: "Temperature and precipitation are two of the key drivers of ecosystem processes."

5. Referee: 14322-15 I had to read the phrase 'alleviate competitive exclusion of sub-dominant species' several times – the idea is that difficult conditions could increase biodiversity. Try to rephrase in positive language.

Answer: We agree with the referee and changed the sentence to: "At the level of plant communities and long-term response, the stress induced by drought may modify competition and facilitation, or it may tip the balance towards a state where only stress resistant plant species are able to survive (McDowell et al., 2008).

#### Material and methods

6. Referee: The second, third and fourth paragraphs of 2.1 are repetitive. Could all this be summarized in a table?

Answer: We agree with the referee, shortened the section, and inserted a table. See comment #6 of referee 1 and the supplement therein.

7. Referee: 14326-17 Is re-entry of water not also a problem (or more of a problem) at flat sites?

Answer: Steep angled slopes are prone to overland flow. Therefore, at steep slopes, water transfer from outside under the roofs can be a problem, which we wanted to avoid. We choose flat angled plots, where water (from the barrels) is following gravity away from the plots, but are not too steep to be prone to overland flow. (Please see also the answers to comment no. 1, 10, and 11 of referee#1, and comment no. 1 of referee#2).

8. Referee: 14327-26 I found this adjustment calculation hard to follow in text. Could

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you include a formula to show the working?

Answer: We agree with the referee here and added a formula (please see supplement).

9. Referee: 14329-4 What is matric potential?

Answer: Matric potential is part of the soil water potential; some use the terms as interchangeable.

10. Referee: LAI<sub>sp</sub> – describe this as species-level leaf area index. See next point about SLA. 11. Referee: Specific leaf area (SLA) has a widely accepted definition in the literature (mm<sup>2</sup> mg<sup>-1</sup>) which is not what you want here. Need to find another term for LA<sub>sp</sub>.

Answer: We now don't refer to specific leaf area index any longer but just to leaf area index (LAI), a term which is generally used to indicate the leaf area per ground area. We now also do not refer any longer to specific leaf area when we refer to the area of an average leaf of a species.

12. Referee: Useful to explain what a phytometer is. I take it as a group of plants used as a measure of physiological responses, but it sounds like a piece of equipment.

Answer: The term "phytometer" is a commonly used term for a plant planted into an existing community and used as a standardized measure of the abiotic and biotic growth conditions. But we agree with the referee and changed the sentence 14330 L19 to: "For further insight on the effect of drought on growth, we planted phytometers (proxy-plants used as a measure of plant physical response) of *Fagus sylvatica* L. on all 90 subplots."

#### Results

13. Referee: The second paragraph of 3.1 dealing with the rainfall patterns by site and season is difficult to read and follow – lots of repetition. And I found Figure 4 difficult to interpret – especially the panels at the top.

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Answer: We agree with the referee and shortened the section. For Figure 4 we choose to present our (precipitation) input data as cumulated sums – an illustration often used for hydrological purposes. Since the legend and figure description state it as cumulated sums, we do not fully understand the point raised by the referee.

14. Referee: Section 3.2 – much of this (up to the sentence starting ‘Air temperature ..’) doesn’t look like it belongs in the Results section.

Answer: We changed the section in agreement with the referee #1. The section (parts) reads now as follows: “. . .Because elevation of air temperature and humidity has significant effects on growth, germination, transpiration and water uptake of plants, on microbial activity and on soil evaporation, we aimed at avoiding any alteration of air temperature and humidity as well as radiation. Based on the monitored air temperature, air humidity and soil temperature at the main roof and the neighboring main control subplot, we tested whether the roofing had a measureable effect on these variables. Air temperature and humidity were not affected by the roofing on none of the experimental sites (Figure 5). The 15 min readings on control plot and under the roof are not significantly different (except plot HEW3) according to the Wilcoxon-Mann-Whitney rank sum test. . . .”

15. Referee: Section 3.3. I had great difficulty understanding Figure 6. No statistical analysis is offered to underline the effects at Site/Plot/Depth/Distance – not all of these classes are different from the control plots.

Answer: We provided Figure 6 to give an overview of the soil moisture state on the roofed subplots compared to the control subplots. We agree with the referee and explained the term soil water deficit in the caption of the Figure. The caption now read as follows: “Soil water deficit (soil water content of control minus roofed subplot) of the main subplots. All values originate from May 2013, except the values from HEW47 (April 2013), due to probe failure. “–“ marks missing values.”

16. Referee: “The reduction was strongest in (in) the top soil layer (5cm) of all plots

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at a distance of 3 and 4 m from the centre tree.” But is that true? 2 m bars look just as strong in AEW8 and AEW13. And reductions in AEW8 are most pronounced at a depth of 15 cm (3 m distance).

Answer: We agree with the referee and changed the sentence to: “The reduction was strongest in the top soil layer (5 cm) of all plots at a distance of 3 and 4m from the center tree. In addition, the 2 m distance (5 cm depths) of AEW8 and AEW13 and the 3 m distance (15 cm depths) of AEW8 are showing high soil moisture deficits.”

17. Referee: Section 3.4 No statistical justification is given for the assertion that “There were no significant differences between the total coverage of the sites”. I would argue that 40.3% is much greater than 27.9%.

Answer: We agree with the referee that the values indicated a significant difference. However we used a linear mixed effects model (lme) with plot and subplot as random factors. Because of the high variance of the cover per plot (land-use) and subplot, we found no significant difference between the sites ( $p = 0.6715$ ). The high variance resulted from the three different land-use types at the three sites which was all over very similar at the three sites. With relatively low coverage at the unmanaged beech forest and very high coverage at the managed coniferous plots.

18. Referee: Table 3 – again we are shown no results of the Kruskal-Wallis test. For example at AEW8, at first glance 0.796 Control looks much higher than 0.462 Roofed.

Answer: We have now changed several text passages associated to the raised issue. section 2.5: “We applied t- tests to assess the differences in the LAIsp and for species richness between the roof and control treatment using R (R-3.0.2, The R Foundation for Statistical Computing 2013).”

section 3.4: “In late summer 2012, i.e. at the end of the first growing season with the drought treatment, there were significant differences in LAI between the roof and control subplots at the managed beech plot at the Schwäbische Alb (AEW29;  $p = 0.001$ )

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and at the intensive managed conifer plot at the Hainich exploratory (HEW03;  $p = 0.01$ ) (Table 3). The species richness of the understorey plant community were significantly higher at the managed roof subplot of the Hainich exploratory compared to the control subplot (HEW47,  $p = 0.004$ )."

section 4.3: "Only a small number of plots have shown a significant change in specific LAI and species richness as a consequence of the treatment." table 3. : We include in the table legends: t- tests were applied to assess the differences in the LAIsp and for species richness between the roof and control treatment \*  $p < 0.05$ , \*\*  $p < 0.01$ . Furthermore we include two more rows in the table (roof vs. control) to show the results of the t-tests.

19. Referee: Table 4 – I was confused by the values (p-values? Values are error probabilities?) What does the (intercept) line refer to?

Answer: We agree with the referees and changed the caption of the Table. The intercept indicates that the overall mean is different from zero. The caption of the Table reads now as follows: "Results of the linear mixed model for the leaf stomatal conductance (gs) as a function of site, drought and competition of the *Fagus sylvatica* phytometers in July and September 2012 (spring data not shown). Values are p-values. Significant probabilities ( $p < 0.05$ ) are shown on bold; den df = degrees of freedom."

20. Referee: Figure 7 – The boxes are squashed because of the single high outlier at SEW. Could this be excluded from the analysis? The y-axis then would be much shorter and comparisons among the boxes much easier. Lettering could be applied to the boxes to indicate those that are significantly different, one from the other.

Answer: We agree with the referee and changed Figure 7 accordingly (see Figure 1 at the end of this comment).

#### Discussion

23. Referee: Section 4.2: I don't understand the meaning of "...points to a comparable

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coupling of airspace on both subplots."

Answer: We agree with the referee and changed the sentence to: "...indicates a comparable coupling of the airspace close to the ground to the atmosphere on both subplots."

24. Referee: I don't agree with the statement "The drought treatment clearly reduced soil moisture content in all depths in all plots."

Answer: We agree with the referee and changed the sentence to: "The drought treatment clearly reduced soil moisture content in all depths in all plots (exceptions are the 5 cm depth of SEW48 and SEW49, the 60 cm depths of HEW47 and SEW49)."

25. Referee: Conclusions – tie these back to explicit aims laid out in the Introduction.

Answer: We have now focused on the aims we stated in the introduction.

#### Technical corrections

26. Watch the spelling of understory (instances of understorey also).

Answer: We checked spelling and changed where needed.

27. Exploratories is not a word I know. Explorations?

Answer: "Biodiversity Exploratories" is a fixed term, introduced for a large scale and long term functional biodiversity research platform. Refer to Markus Fischer et al. 2010, *Basic and Applied Ecology*, 473 – 485. (See also <http://www.biodiversity-exploratories.de/1/home/>). We used the facilities for our research.

28. Can you find another term for sub-subplot? Minor-plot?

Answer: We do not agree with the referee here; the change of the word sub-subplot to minor plot would not increase the readability or understandability.

29. 14322-9 Rephrase e.g. "...as might be the case in a future Europe.

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Answer: We agree with the referee and changed the sentence to: "It remains unclear, how the forest understory will respond to continuously reduced precipitation, as it might be in the case in a future Europe under climate change (Kreuzwieser and Gessler, 2010)."

30. 14323-8 Omit 'to be able'.

Answer: We agree with the referee and changed the sentence to: "The knowledge of such mechanisms related to the understory response to drought need to be included in current forest growth models in order to understand all aspects of the system – including natural regeneration – under climate change."

31. 14323-10 Omit 'above the forest floor'.

Answer: We agree with the referee and changed the sentence to: "We thus propose to experimentally manipulate precipitation and investigate in detail the consequences for soil moisture, soil hydrological functions, and water uptake as well as vegetation structure but also allowing to include more in-depth studies such as assessments of the microbial community structure."

32. 14323-20:23 Really belongs in the Methods

Answer: We do think that this manuscript focuses on the description of a roof system allowing flexible reductions of precipitation in forest understory ecosystems. Therefore we are of the strong opinion that the section the referee refers to fits well to the end of the introduction.

33. 14326-27 Replace 'random' with variable.

Answer: We agree with the referee and replaced 'random' with 'variable'. The sentence is now as follows: "This roof system can reduce rainfall between 11 and 100% and due to its design, rainfall exclusion is variable and not persistent in space."

34. 14330-16 Replace 'per' with of.

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Answer: We agree with the referee and replaced 'per' with 'of'. The sentence is now as follows: "...where Nspecies is the total number of species found on the quadratic area of 2.45 m<sup>2</sup>."

35. 14331-8 Briefly describe the chambers rather than asking us to look up Yopez et al.

Answer: We agree with the referee have now added additional information to the respective section. The paragraph now reads as follows: "In the field, gas-exchange chambers (transparent Perspex, size: 52 x 77.5 x 78.5cm, A = 0.61 m<sup>2</sup>) comparable to the ones described in Yopez et al. (2005) were used for measuring understory evapotranspiration (ET) rates. The chambers were open to the soil, sealed with rubber foam gaskets to the ground and were use as closed systems to assess the build up of water vapour from soil evaporation and plant transpiration. Measurements were made three times in 2012 (spring, early summer, late summer) at all nine plots. ET rates were determined on the control subplots and on the roof subplots. The increase in water vapor in the closed chambers was measured with a cavity ringdown laser spectrometer (PICARRO L1102-I, Picarro Inc.) directly in the field, with four replicates per control subplot and per roof subplot between 10:00 a.m. and 15:00 p.m. (CEST). The chamber air was circulated through the isotope water analyzer via a low absorption tube using the Picarro pump (flow rate <0.4 l min<sup>-1</sup>) and fed back again in the chamber headspace. For each chamber, a measurement lasted 10-12 minutes, and a fan provided mixing of the air in the gas exchange headspace."

36. 14331-14 What is (MESZ)?

Answer: We agree with the referee and changed 'MESZ' to 'CEST'. The sentence is now as follows: "The increase in water vapor in the closed chambers was measured ... between 10:00 a.m. and 15:00 p.m. (CEST)."

37. 14333-3 '...we had to increase the reduction..' needs to be rephrased

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Answer: We agree with the referee and changed the sentence to: "To compensate the high precipitation input, we had to raise the exclusion (Fig. 4, blue bars) from 30 % (mean value) to 50 %, which resulted in a reduction below the target (699 mm) of 11 %."

38. 14333-13 'excluded' is better here than 'reduced'

Answer: We agree with the referee and changed the sentence to: "In total, 221mm were excluded in the Schwäbische Alb sites in 2012 which resulted in an incoming precipitation under the roofs of 719 mm."

39. 14335-6 coverage here refers to vegetation, but elsewhere you talk about roof coverage. Important to be explicit and make these distinctions clear for the reader.

Answer: We agree with the referee and cleared the sentence to: "There were no significant differences between the total vegetation coverage of the sites. . ."

40. 14335-23 should refer to Table 4 not Table 3.

Answer: We agree with the referee and changed the reference to Table 4.

41. 14336-14 Replace 'calculative' with 'calculation'

Answer: We agree with the referee and changed the sentence to: "Possible problems may occur, using our technique in very extraordinary dry or wet years, although we did not detect such meteorological circumstances in the 1950–2010 records in all our regions when we tested our design in terms of figures."

42. 14336-17 Replace 'reducing' with 'excluding'

Answer: We agree with the referee and changed the sentence to: "In contrast to . . . , it was possible to reduce the precipitation to a certain level over the year, instead of excluding the total precipitation input during a time period. . ."

43. 14337-8 Replace '...can reach a maximum of..' with '..by as much as..'

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Answer: We agree with the referee and changed the sentence to: "The shielding can raise mean air temperature . . . and can reach as much as 3.2 °C. . ."

44. 14338-23 Rephrase e.g. "Changes in ecosystem functioning occur after stress conditions exceed. . ."

Answer: We agree with the referee and changed the sentence to: "Changes in ecosystem functioning occur after stress conditions exceed a certain level of climate severity threshold, which cannot predicted until now (Bahn et al., 2014; Vicca et al., 2012)."

45. 14339-22 Rephrase e.g. " . . . a valid, and more realistic, alternative to the common. . ."

Answer: We agree with the referee and changed the sentence to: "We conclude that our innovative roofing construction is a valid, and more realistic, alternative to the common drought simulation practice of total rainfall reduction."

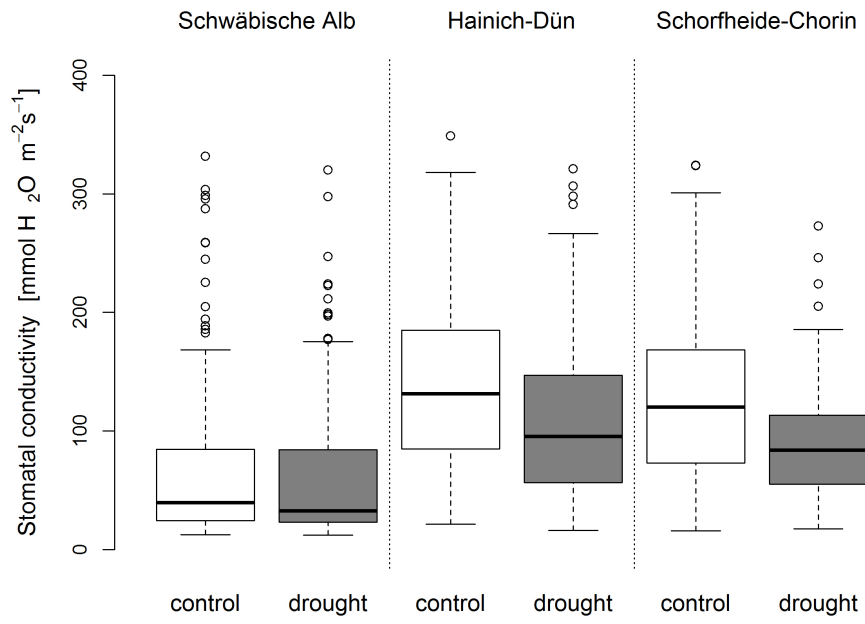
Please also note the supplement to this comment:

<http://www.biogeosciences-discuss.net/11/C7700/2014/bgd-11-C7700-2014-supplement.pdf>

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Interactive comment on Biogeosciences Discuss., 11, 14319, 2014.

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**Fig. 1.** Leaf stomatal conductance at the three experimental sites in July 2012. The boxes show medians and quartiles, the whiskers show 1.5 times the interquartile range of the data.